Available online at www.sciencedirect.com
ScienceDirect
Agriculture and Agricultural Science Procedia 5 (2015) 17 – 21
Agriculture and Agricultural Science Procedia

1st International Conference on Asian Highland Natural Resources Management, AsiaHiLand 2015

Reduce burning in maize production by relay cropping with legume

Adirek Punyalue[a], Jedsada Jongjaidee[a], Sansanee Jamjod[b] and Benjavan Rerkasem[b] *

[a] *Highland Research and Development Institute (Public Organization),65 Suthep Rood, Chiang Mai, 50200, Thailand*
[b] *Faculty of Agriculture Chiang Mai University, Suthep Rood, Chiang Mai, 50200, Thailand*

ABSTRACT

Maize production in Thailand has moved to the highlands, where residues of crop and weeds are burned to prepare land for the new crop. This study was done to compare relay cropping of maize with legumes to reduce burning in the highlands at Pang-da Royal Agriculture Station. The experiment was conducted with 3 maize-legume relay treatments (maize + lablab, maize + ricebean and maize + cowpea) and maize monoculture (farmer's practice) with 3 replicates in the wet season of 2012 and 2013. The maize grain yield was 5.19 Mg/ha in maize-mono, but 24 - 53% higher in the maize-legume relays. There was additional legume grain yield of 0.13 Mg/ha in maize + lablab, 0.30 Mg/ha in maize + ricebean and 0.73 Mg/ha in maize + cowpea. Contribution from biological N_2 fixation in legumes is most likely to have contributed to the total above ground nitrogen of 288 kg N/ha in maize + lablab, 177 kg N/ha in maize + ricebean and 186 kg N/ha in maize + cowpea, compared with 101 kg N/ha in maize-mono. While the maize-mono residue was lost in burning, 136 kg N/ha was retained in the maize+lablab bean residue, 68 kg N/ha in maize + ricebean residue and 36 kg N/ha in maize + cowpea residue. These maize + legume relay cropping systems are promising as a means to reduce burning in the highlands while increasing maize yield at the same time.

Keywords: residue; burning; maize; nitrogen balance; legume; relay cropping

* Adirek Punyalue. Tel.: +6-681-716-1988; fax: +6-605-332-8494.
E-mail address: adirek_p311@hotmail.com

doi:10.1016/j.aaspro.2015.08.003

1. Introduction

Maize is grown on 1.14 million ha in Thailand, where 0.7 million ha is in Northern region (Office of Agricultural Economics, 2014). Most of the maize in the North of Thailand is produced rainfed in the highlands. Generally, after the maize harvest farmers would leave the stover (e.g. leaves, stalks and husks) in the field until next crop. To prepare land for the new crop in March - April, maize stover and weeds are traditionally slashed and burned. Slash and burn, however, has many impacts on the environment. Repeated burning of the vegetation may influence biological functions of organic matter, its decomposition, carbon sequestration and soil aggregation, and directly through a loss of organic matter input (Ladd et al., 1994; Quoted in Giller et al., 1997). Moreover, biomass burning contributes to gaseous and particulate pollutants in the atmosphere with detrimental impact on global atmospheric chemistry (Xinghua et al., 2007). Slash and burn to grow maize is considered to contribute to the very high concentrations of atmospheric particulate matter during the residue burning season in the Upper North, e.g. 437.6 µg/m^3 (PM10) recorded in on March 8th, 2012 in Chiang Rai, compared with the safe standard of 120 µg/m^3 (Pollution Control Department, 2012). Burning crop residues has many adverse effects on soil fertility and thus farmers' income. On steep slopes in the highlands the lack of surface cover makes the soil prone to erosion, soil fertility declines with the loss of surface soil. Nitrogen, the nutrient most frequently limiting maize yield (Boonlertnirun and Jompuk, 2011), and sulphur are lost to the atmosphere in the fire. The harmful effects of residue burning in maize production in the highland would be removed when the burning is stopped. However, an alternative to the residue burning is needed for maize production in the highlands.Many local legumes have been found to accumulate large amounts of nitrogen when intercropped with maize. These include cowpea (*Vigna unguiculata*, Ofori and Stern, 1986), lablab bean (*Lablab purpureus*, Devkota and Rerkasem, 2000) and rice bean (*Vigna unguiculata*, Rerkasem and Rerkasem, 1988). The nutrient balance was used as an indicator of a system's ability to maintain soil fertility. Nutrients in excess of crop requirements are prone to leaching while nutrients in deficit of crop requirements reduce soil fertility, which in turn lowers crop productivity. Maize crops in Uganda were found negative balance in N, P was 104, 13 kg/ha/year and 82 kg/ha/year in K (Wortman and Kaizzi, 1998; Roy et al., 2003).

Nutrient input and output flow in arable farming, N input highest from fertilizer was 64% and output highest from arable crop was 33%, P input highest from fertilizer was 57% and output highest from losses was 55% and K, P inputs highest from soil was 41% and output highest from crop residue was 65% (Sheldrick, Syers and Lingard (2002) ; Roy et al. (2003)) Quantifying the nutrient balance of maize-involved crop rotations under different fertilizer and residue management practices can help to develop effective policies addressing nutrient-related environmental problems, and achieve sustainable maize stover harvest (Khanal et al., 2014). Wilhelm et al. (2004) suggest that removal of crop residues from the field must balance against impacting the environment (soil erosion), maintaining soil matter levels and preserving or enhancing productivity. Due to the negative impacts of slash and burn plus monoculture in the highlands, above ground residue burning needs to be minimized and residue must be retained on the soil to maintain and increase soil fertility, soil biodiversity, minimizing erosion and protecting soil quality and maintain of productivity. In this experiment, maize-legume cropping system were chosen. The objective of this study was to evaluate productivity and nitrogen balance of three maize-legume cropping systems as alternatives to farmers' common practice of maize growing with residue burning.

2. Materials and method

The experiment was conducted over 3 growing seasons, during the crop year 2010 to 2013 at Pang-da Royal Agriculture Station, in Chiang Mai province. Experimental design was RCBD with 4 treatments in 3 replicates of each. There were:

1) Farmer's practice of maize crop with residue burning (maize monoculture)
2) Maize relay with lablab bean (Maize + lablab bean)
3) Maize relay with rice bean (Maize +rice bean)
4) Maize relay with cowpea (Maize +cowpea)

Maize was grown at 75 x 25 cm spacing in 5 X 6 meter/plots at the beginning of the rainy season (early May). With no burning, the legumes were sown among the maize plants in late August, 30 days before the maize harvest, at the 19 kg/ha growth among maize plant and 25 cm of plant spacing. In the next season maize in the treatments with legumes was sown directly into the residue left from the previous year, while in the treatment without legume the residue was burned before sowing maize. Application fertilizer, 46-0-0 at 30 day after growing rate 156 kg/ha and 16-20-0 at 60 day after growing rate 156 kg/ha.

2.1. Collection of Data

1) **Soil sampling:** Soil samples were collected before planting of maize in April in total of 15 holes/plot **and** analyzed for organic matter (OM), nitrogen (N), phosphorus (P) and potassium (K)
2) **Seed yield:** M**aize seed yield was** collected in 12 hills (2.25 m^2) and seed yield beans were collected in 1 m^2 then analyzed for nitrogen (N), phosphorus (P) and potassium (K) (analysis by Soil Science Laboratory).
3) **Residues dry weight:** residues of **maize** were collected in 12 hill (2.25 m^2) and **bean** were collected in 1 m^2 on reproductive stage then analyzed for , nitrogen (N), phosphorus (P) and potassium (K) (analysis by soil Science Laboratory).

Analyses of soil and plant samples were conducted by Soil Science Laboratory, Chiang Mai University.

3. Result

In the 3th years of experimentation there was minor variation (not significant at P<0.05) in pH, organic matter, organic carbon, nitrogen, phosphorus and potassium among the treatments. Soil pH ranged from 5.12 - 5.66 with average of 5.44, and the highest pH found in maize + cowpea and lowest in maize + lablab bean. Organic carbon ranged from 1.96 - 2.07%, average of 2.02% and the highest in maize Farmers' practice and lowest in maize-cowpea. Nitrogen ranged from 0.11 - 0.25%, with average of 0.14%, and the highest found in maize + lablab bean and lowest in maize + rice bean. Available P ranged from 5.70 - 8.10 ppm with average of 6.89 ppm, the highest found in maize + lablab bean and lowest in Farmers' practice. Extractable K ranged from 220 - 256 ppm with average of 243 ppm, and the highest found in maize + lablab bean and lowest in maize mono (Table 1).

Table 1 Soil fertility characteristics in 4 cropping systems in 2013.

No	Treatment	pH	OC (%)	N (%)	P (*ppm*)	K (*ppm*)
1	Farmers' practice	5.62	2.07	0.12	5.70	220
2	Maize + lablab bean	5.12	2.02	0.25	8.10	256
3	Maize + rice bean	5.36	2.01	0.07	6.11	250
4	Maize + cowpea	5.66	1.96	0.11	7.65	247
	mean	5.44	2.02	0.14	6.89	243
	F-test	ns	ns	ns	ns	ns
	CV (%)	6.56	6.86	24.49	25.99	17

The cropping systems with legumes significantly increased (P<0.05) grain yield of both maize and also produced some legume grain (Table 2). The highest maize grain yield was from maize + lablab bean and lowest in maize with farmer's practice of residue burning. Maize + cowpea gave slightly less maize grain yield than maize + lablab bean. The maize grain yield from maize+rice bean was lowest among the cropping systems with legume, but was still significantly higher than the yield from farmer's practice of maize grown with residue burning. The introduction of legumes also gave legume grain yield that ranged from 0.13 Mg/ha with lablab bean, 0.30 Mg/ha with rice bean and 0.73 Mg/ha with cowpea.

Table 2 Grain yield of maize and legume in 4 cropping systems in 2013.

No	Treatment	Maize (*Mg/ha*)	Legume (*Mg/ha*)
1	Farmer's practice	5.19 c	0 d
2	Maize + lablab bean	7.97 a	0.13 c
3	Maize + rice bean	6.45 b	0.30 b
4	Maize + cowpea	7.33 a	0.73 a
	mean	6.73	0.28
	F-test	**	**
	LSD .05	0.81	0.06
	CV (%)	6.02	10.2

Crop residues in cropping systems: The result was not significantly different (P>0.05) in maize residue, but significantly different in 3 kind of legumes (Table 3). Maize residue ranged from 2.6 - 3.9 Mg/ha with the average at 3.3 Mg/ha. The farmer's practices had slightly less maize residue than maize + legume. When compared among maize + legume, maize + lablab bean was slightly higher than maize + rice bean and maize + cowpea. For Legume residue, the highest was 3.9 Mg/ha in lablab bean, 2.5 Mg/ha in rice bean and the lowest 0.5 Mg/ha in cowpea, respectively.

Table 3 Crop residue maize and legume (Mg/ha) in 4 cropping systems in 2013.

No	Treatment	Maize (*Mg/ha*)	Legume (*Mg/ha*)	Total (*Mg/ha*)
1	Farmer's practice	2.6	0.0 d	2.62
2	Maize + lablab bean	3.9	3.9 a	7.77
3	Maize + rice bean	3.3	2.5 b	5.82
4	Maize + cowpea	3.3	0.5 c	3.87
	mean	3.3	1.7	
	F-test	ns	**	
	LSD .05	-	0.2	
	CV (%)	14.6	6.2	

Nitrogen in maize residue and grain yield was not significantly different (P>0.05) (Table 4) Values for N concentration in maize residue ranged from 18 N kg/ha in farmer's practice to 27 N kg/ha in maize + lablab bean. N concentration in maize grain yield ranged from 83 N kg/ha in farmer's practice to 147 N kg/ha in maize + lablab bean.

N concentration in legume residue and grain yield was significantly different (P<0.05). Legume residue was found highest in lablab bean at 109 N kg/ha, 44 N kg/ha in rice bean and 16 N kg/ha in cowpea. Nitrogen concentration in legume grain yield found highest in cowpea at 26 N kg/ha, 12 N kg/ha in rice bean and 5 N kg/ha in lablab bean.

Nitrogen above ground of cropping systems, N residue retained in the soils were found in Farmer's practice, maize + lablab bean, maize + rice bean and maize + cowpea with 18 N kg/ha, 136 N kg/ha, 68 N kg/ha and 36 N kg/ha, respectively.

Nitrogen in harvest yields found in maize farmer's practice, maize + lablab bean, maize + rice bean and maize + cowpea were 83 N kg/ ha, 152 N kg/ha, 109 kg/ha and 150 N kg/ha, respectively.

Total above ground in maize + legume were 288 N kg/ha in maize + lablab bean, 177 N kg/ha in maize + rice bean and 186 N kg/ha in maize + cowpea (Table 4).

Table 4 N balance (Mg/ha) in 4 cropping systems in 2013.

		N residue (*N kg/ha*)			N in harvested yield (*N kg/ha*)			Total above ground
no	Treatment	maize	legume	total	maize	legume	total	(*N kg/ha*)
1	Farmer's practice	18	0 c	18	83	0 c	83	101
2	Maize + lablab bean	27	109 a	136	147	5 bc	152	288
3	Maize + rice bean	24	44 b	68	97	12 b	109	177
4	Maize + cowpea	19	16 bc	36	123	26 a	150	186
	mean	23	42		113	11		
	F-test	ns	**		ns	**		
	LSD .05	-	29		-	8		
	CV (%)	23	34		22	38		

4. Discussion and conclusion

In addition to lessening the release of particulates to the atmosphere, replacing residue burning in highland maize production with introduction of legumes was found to bring three direct benefits to farmers, with different level of benefits from different legumes. Firstly, grain yield was increased by 24% to 53%, with some of the yield from grain legumes that are of higher nutritional and market value than maize. Secondly, the amount of residue left for protection of the soil surface was increased by 48% to 197%. Thirdly, above ground nitrogen was increased by 75% to 185% by the legume introduction. The benefits from maize + lablab bean were greatest in all parameters provided, except in its own grain yield.

In farmer's field at a highland site in Mae Hong Son, rice field with natural vegetation in between the rice crops was found to contain 82 kg N/ha above grown, whereas the field planted with rice bean contained 223 kg N/ha and with lablab 319 kg N/ha (Chaiwong et al., 2012). When intercropped with maize at Chiang Mai, lablab was recorded to fix 132 kg N/ha from the air (Devkota and Rerkasem, 2000). Rice bean, on the other hand, was reported to derive 86% of its total plant N from the atmosphere when intercropped with maize compared with only 27% to 36% when grown in monoculture (Rerkasem et al., 1988). All three legumes in the study were well nodulated, with healthy pink nodules, indicating their capacity to fix N_2 from the atmosphere.

Maize grain yield in maize relay cropping with legume had higher yield than farmer's practice. In rice grain yield in lablab and rice bean produced green manure increasing by 36% to 44% from the increasing nitrogen by 174% to 289% (Chaiwong et al., 2012). Maize grain yield was increased by intercropping with lablab bean if lablab bean was cut at 40 DAS by 15% to 18% and lablab add N in to the soil at 132 kg N/ha (Devkota and Rerkasem, 2000). In the Pak Chong soil series, the maize grain yield increased with increase N fertilizer by 7% to 22% (Sipaseuth et al., 2007)

In conclusion, maize+legume relay cropping systems are promising as a means to reduce burning in the highlands and improving maize yield at the same time, with lablab bean being the best possible candidate legume.

5. References

Boonlertnirun K and Jompuk C., 2011. Nitrogen use Efficiency and Low Nitrogen Tolerance in Waxy Corn. Khon Kaen Agriculture Journal. 39, 231-240.

Chaiwong U, Yimyam N, Rerkasem K and Rerkasem B., 2012. Green Manures for Highland Paddy in a Mountainous Area. Chiang Mai University Journal of Natural Sciences. 11, 103-107.

Devkota NR and Rerkasem B., 2000. Effects of Cutting on the Nitrogen Economy and Dry Matter Yield of Lablab Grown Under Monoculture and Intercropped with Maize in Northern Thailand. Experimental Agriculture. 36, 459-468.

Giller K.E., Beare M.H., Lavell P., Izac and Swift M.J., 1997. Agricultural Intensification, Soil Biodiversity and Agro Ecosystem Function. Applied Soil Ecology 6, 3-16.

Khanal S.,Anex R.P., Gelder B.K., and Wolter C., 2014. Nitrogen Balance in Iowa and the Implications of Corn Stover Harvesting. Agriculture, Ecosystems and Environment, 183. 21-30.

Office of Agricultural Economics, 2014. Maize Planting Areas and Yield/rai in 2011-2013 (Online). Available: http://www.oae.go.th/download/prcai/DryCrop/maize52-54.pdf.(January 5, 2015)

Ofori F and Stern WR., 1986. Maize/Cowpea Intercrop System: Effect of Nitrogen Fertilizer on Productivity and Efficiency. Field Crop Research. 14, 247–261.

Pollution control Department, 2012, Thailand's Air Quality and Situation Reports (Online).Available: http://air4thai.pcd.go.th/web/index.php. (March 20,2012)

Rerkasem, B., and Rerkasem, K., 1988. Yields and Nitrogen Nutrition of Intercropped Maize and Rice bean (*Vigna umbellata* [Thunb.] Ohwi and Ohashi). Plant Soil 108, 151-162.

Roy R.N., Misra R.V., Lesschen J.P. and Smaling E.M. 2003. Assessment of Soil Nutrient Balance Approaches and Methologies. Viale delle Terme di Caracalla, 00100 Rome, Italy . 79.

Sipaseuth N., Attanandana T. and Yost R.S., 2007. Nitrogen Fertilizer Response of Maize on some Important Soils from DSSAT Software Prediction. Kasetsart Journal (Natural Science) 41, 21-27.

Wilhelm W.W., Johnson J.M.F., Hatfield J.L., Voorhees W.B., and Linden D.R., 2004. Crop and Soil Productivity Response to Maize Residue Removal: A Literature Review. Agronomy Journal Volum 96.

Xinghua, Li, Shuxiao W., LeiI D., Jiming H., Chao L., Yaosheng C., and Liu Y., 2007. Particulate and Trace Gas Emissions from Open Burning of Wheat Straw and Maize Stover in China. Environment Science Technology. 41, 6052-6058.